# PATENT ABSTRACTS OF JAPAN

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(71)Applicant : TOSHIBA CORP
(72)Inventor : YOSHIKAWA MASAHISA
KAMIGUCHI YUZO
TAKAGISHI MASAYUKI
YUASA HIROMI

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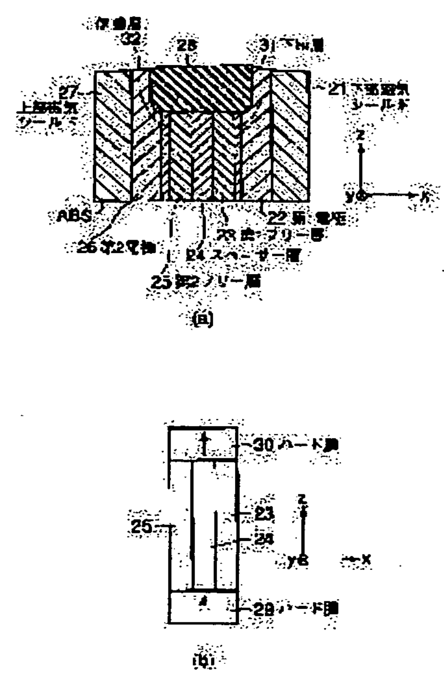
## (54) MAGNETO-RESISTIVE EFFECT HEAD AND PERPENDICULAR MAGNETIC RECORDING/REPRODUCING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a magneto-resistive effect head wherein a gap is narrowed corresponding to a high increasing record density.
SOLUTION: The magneto-resistive effect head is provided with a first magnetic free layer 23 and a second magnetic free layer 25 having film surfaces arranged substantially vertical to a medium opposite surface, an intermediate layer 24 held between these magnetic free layers, a substrate layer 31, and a protective layer 32. The substrate layer, the first magnetic free layer, the intermediate layer, the second magnetic free layer, and the protective layer are sequentially laminated in this order. The magneto-resistive effect head is further provided with a magneto-resistive effect film for independently changing their magnetization directions in accordance with a signal of a magnetic flux from a medium, and exerting a magneto-resistive effect in accordance with the changes of the magnetization directions, a first electrode 22 installed to conduct current substantially vertically to the surface of the magneto-resistive effect film, and electrically connected to the substrate layer, and a second electrode 27 electrically connected to the protective layer.



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1. JP,2002-319112,A

JAPANESE [JP,2002-319112,A]



[Translation done.]

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CLAIMS

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[Claim(s)]
[Claim 1] The 1st magnetization free layer and the 2nd magnetization free layer by which a film surface has been substantially arranged perpendicularly to a data-medium opposed face, It has an interlayer inserted among these magnetization free layers, a substrate layer, and a protective layer. A laminating is carried out to order of a substrate layer, the 1st magnetization free layer, an interlayer, the 2nd magnetization free layer, and a protective layer one by one. A magneto-resistive effect film which said 1st magnetization free layer and the 2nd magnetization free layer change the magnetization direction independently according to signal magnetic flux from data medium, and demonstrates a magneto-resistive effect according to change of each magnetization direction, A magneto-resistive effect arm head which has the 2nd electrode electrically connected to the 1st electrode and a protective layer which were prepared in order to energize current perpendicularly substantially to a film surface of said magneto-resistive effect film, and were electrically connected to a substrate layer.
[Claim 2] Furthermore, a magneto-resistive effect arm head according to claim 1 which has one pair of magnetic shielding prepared in both sides of structure formed with said 1st electrode, said magneto-resistive effect film, and said 2nd electrode.
[Claim 3] Each of one pair of said magnetic shielding is a magneto-resistive effect arm head according to claim 2 by which electrical connection is carried out to said 1st or 2nd electrode.
[Claim 4] A magneto-resistive effect arm head according to claim 1 in which said interlayer is formed by conductive non-magnetic layer.
[Claim 5] A magneto-resistive effect arm head according to claim 4 currently formed with at least one sort of metals chosen from a group which said interlayer becomes from Be, aluminum, Mg, calcium, Cu, Au, Ag, Rh, Ru, and Ir.
[Claim 6] Said interlayer is a magneto-resistive effect arm head according to claim 1 which has a three-tiered structure including one pair of 1st interlayers who touch said 1st magnetization free layer or the 2nd magnetization free layer, respectively, and the 2nd interlayer inserted into said one pair of 1st interlayers.
[Claim 7] It is the magneto-resistive effect arm head according to claim 6 formed from at least one sort of metals chosen from a group which said 2nd interlayer becomes from Be, aluminum, Mg, and calcium by forming said 1st interlayer from at least one sort of metals chosen from a group which consists of Cu, Au, Ag, Rh, Ru, and Ir.
[Claim 8] A magneto-resistive effect arm head according to claim 1 in which said interlayer is formed by oxide layer.

[Claim 9] A magneto-resistive effect arm head according to claim 8 currently formed by at least one layer chosen from a group which said oxide layer becomes from aluminum oxide, Si oxide, Fe oxide, Cr oxide, Ta oxide, nickel oxide, and a perovskite mold oxide.
[Claim 10] Said oxide layer thickness is a magneto-resistive effect arm head according to claim 8 which is about 5nm or less.
[Claim 11] A magneto-resistive effect arm head according to claim 1 in which said middle class is formed by sandwiches film of a cascade screen of [a metal layer / oxide layer, or a CHITSU ghost layer], [a metal layer / oxide layer / metal layer], or a [a metal layer / CHITSU ghost layer / metal layer].
[Claim 12] A magneto-resistive effect arm head according to claim 11 currently formed by at least one layer chosen from a group which said oxide layer becomes from aluminum oxide, Si oxide, Fe oxide, a perovskite mold oxide, Ta oxide, Cr oxide, and nickel oxide.
[Claim 13] Furthermore, a magneto-resistive effect arm head according to claim 1 which has one pair of hard bias films which give a magnetic anisotropy substantially to said 1st magnetization free layer and the 2nd magnetization free layer which were formed in both ends which meet crosswise [ of a magneto-resistive effect film containing said 1st magnetization free layer, an interlayer, and the 2nd magnetization free layer / truck ] in the same direction.
[Claim 14] A magneto-resistive effect arm head according to claim 1 characterized by providing the following Furthermore, 1st 1 to antiferromagnetism film which is formed in contact with both ends which meet crosswise [ of said 1st magnetization free layer / truck ], and gives a magnetic anisotropy to said 1st magnetization free layer in the predetermined direction 2nd 1 to antiferromagnetism film which is formed in contact with both ends which meet crosswise [ of said 2nd magnetization free layer / truck ], and gives a magnetic anisotropy to said 2nd magnetization free layer in the predetermined direction
[Claim 15] A magneto-resistive effect arm head according to claim 14 on which the direction of a magnetic anisotropy given to said 1st magnetization free layer with said 1st 1 to antiferromagnetism film and the direction of

a magnetic anisotropy given to said 2nd magnetization free layer with said 2nd 1 to antiferromagnetism film make an angle of about 60 degrees - 120 degrees mutually.
[Claim 16] A magneto-resistive effect arm head according to claim 14 distance between said 1st 1 to antiferromagnetism film and whose distance between said 2nd 1 to antiferromagnetism film are about 0.5 micrometers or less.
[Claim 17] A magneto-resistive effect arm head according to claim 16 distance between said 1st 1 to antiferromagnetism film and whose distance between said 2nd 1 to antiferromagnetism film are about 0.2 micrometers or less.
[Claim 18] A vertical-magnetic-recording regenerative apparatus which has vertical-magnetic-recording data medium and a magneto-resistive effect arm head according to claim 1 to 16 which counters vertical-magnetic-recording data medium and is prepared.

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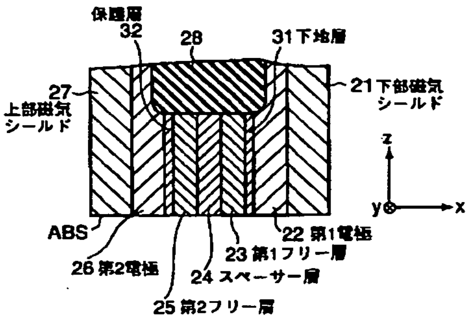
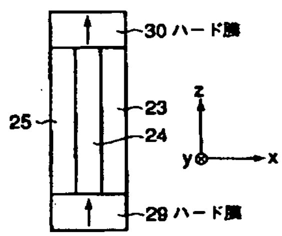
[Translation done.]

Drawing selection Representative drawing




(a)




(b)

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to a magneto-resistive effect arm head and a vertical-magnetic-recording regenerative apparatus.
[0002]
[Description of the Prior Art] In recent years, in magnetic-recording data medium, such as HDD, high recording density-ization is progressing rapidly. The record bit size recorded on a record medium with a raise in recording density becomes small, and signal magnetic flux is also becoming small. In order that the conventional toroidal core mold inductive magnetic head may detect data-medium magnetic flux indirectly according to the electromagnetic-induction effect through a toroidal core, it is impossible to secure sufficient sensitivity to small signal magnetic flux in such a condition. For this reason, the magneto-resistive effect arm head (MR head) which senses data-medium magnetic flux directly in recent years using a magneto-resistive effect has been put in practical use.
[0003] In current, it has the cascade screen [a magnetization fixing layer (pin layer) / interlayer (spacer layer) / magnetization free layer (free layer)], and the spin bulb mold MR (SV-MR) arm head which generates a still huger magneto-resistive effect is making the mainstream. This SV-MR head demonstrates twice [ more than ] as many giant magneto-resistance as this compared with an MR head.
[0004] The conventional SV-MR head has the structure which formed the SV-MR film through the magnetic gap between one pair of magnetic shielding. Moreover, the conventional SV-MR head has been used in the field of SV film from one pair of electrodes as the so-called CIP(Current-in-plane)-MR head which energizes sense current.
[0005] Recently, the so-called CPP(Current-perpendicular-to-plane)-MR head which energizes sense current at right angles to SV film surface from one pair of electrodes is proposed. Since magnetic-reluctance rate of change (MR rate of change) improves further by carrying out CPP energization, a high head output is expectable.
[0006] On the other hand, in the magnetic-recording system within a field, improvement in recording density is approaching the limit for the thermal agitation. For this reason, promising ** of the vertical-magnetic-recording system strong against a thermal agitation is carried out, and the system which combined vertical recording data medium and SV-MR head is proposed.
[0007] Drawing 16 (a) and (b) are the schematic diagrams supposing using it to vertical recording data medium showing the structure of SV-MR head in the already proposed CIP mode. Drawing 17 (a) and (b) are drawings showing the output wave acquired by drawing 16 (a) and SV-MR head of (b), respectively.
[0008] In these systems, narrow gap-ization between an output wave and magnetic shielding poses a problem. That is, it is desirable that the output wave which has a peak by magnetization transition also by the vertical-magnetic-recording system is acquired like the conventional magnetic-recording system within a field. Moreover, in order to correspond to future high recording density-ization, the thickness of SV film prepared between magnetic shielding is thin, and it is desirable that narrow gap-ization can be attained.
[0009] Drawing 16 (a) applies a single SV-MR head to a vertical-magnetic-recording system. In drawing 16 (a), one SV-MR film 10 is formed so that the vertical recording layer 1 may be countered. The SV-MR film 10 has the basic structure which carried out the laminating of the 13/free layer 14 of 12/spacer layers of 11/pin layers of antiferromagnetism layers. The SV-MR film 10 is arranged between one pair of magnetic shielding 15, and 16.
[0010] In this system, as shown in drawing 17 (a), the output wave which changes in monotone corresponding to a record bit is acquired. In this case, in order to acquire the output wave which has a peak by magnetization transition like the conventional magnetic-recording system within a field, a differential circuit must be added to the regenerative-signal processing section. However, a differential circuit has a possibility of increasing a noise. Moreover, since the conventional SV-MR head had the thick antiferromagnetism layer 11, it had the problem that it was difficult to narrow-gap-ize corresponding to a future raise in recording density.
[0011] Drawing 16 (b) applies a dual stripe SV-MR head to a vertical-magnetic-recording system. In drawing 16 (b), one pair of SV-MR films 10 are formed so that the vertical recording layer 1 may be countered. Each SV-MR film 10 has the same basic structure as drawing 16 (a). One pair of SV-MR films 10 are arranged between one pair of magnetic shielding 15, and 16.
[0012] He carries out differential operation of the two SV-MR films, and is trying to acquire the output wave same with being obtained by the conventional magnetic-recording system within a field, as shown in drawing 17 (b) in this system. However, in this structure, since two SV-MR films were formed into a magnetic gap, there was a problem that it could not respond to future high recording density-ization too.

[0013]
[Problem(s) to be Solved by the Invention] The purpose of this invention is to offer the vertical-magnetic-recording regenerative apparatus which carried the magneto-resistive effect arm head in which narrow-gap-izing is possible, and such an arm head corresponding to the raise in recording density.
[0014]
[Means for Solving the Problem] A magneto-resistive effect arm head concerning one mode of this invention The 1st magnetization free layer and the 2nd magnetization free layer by which a film surface has been substantially arranged perpendicularly to a data-medium opposed face, It has an interlayer inserted among these magnetization free layers, a substrate layer, and a protective layer. A laminating is carried out to order of a substrate layer, the 1st magnetization free layer, an interlayer, the 2nd magnetization free layer, and a protective layer one by one. A magneto-resistive effect film which said 1st magnetization free layer and the 2nd magnetization free layer change the magnetization direction independently according to signal magnetic flux from data medium, and demonstrates a magneto-resistive effect according to change of each magnetization direction, It is prepared in order to energize current perpendicularly substantially to a film surface of said magneto-resistive effect film, and it has the 2nd electrode electrically connected to the 1st electrode and a protective layer which were electrically connected to a substrate layer.
[0015] A vertical-magnetic-recording regenerative apparatus concerning other modes of this invention has vertical-magnetic-recording data medium and the above-mentioned magneto-resistive effect arm head which counters vertical-magnetic-recording data medium and is prepared.
[0016]
[Embodiment of the Invention] The magnetic head concerning the operation gestalt of this invention has a magneto-resistive effect film containing the 1st magnetization free layer (the 1 free layer) and the 2nd magnetization free layer (the 2 free layers), the interlayer (spacer layer) inserted among these free layers, a substrate layer, and a protective layer, and the 1st electrode and the 2nd electrode which energize current perpendicularly substantially to the film surface of a magneto-resistive effect film. That is, this magneto-resistive effect film is a CPP-MR film. As for the 1st free layer, the interlayer, and the 2nd free layer, the film surface is substantially arranged perpendicularly to the data-medium opposed face. The laminating of this magneto-resistive effect film is carried out one by one from the substrate side in the order of a substrate layer, the 1st magnetization free layer, an interlayer, the 2nd magnetization free layer, and a protective layer. The magnetization direction of the 1st free layer and the 2nd free layer changes independently according to the signal magnetic flux from data medium (preferably vertical recording data medium). The 1st free layer and the 2nd free layer demonstrate a magneto-resistive effect according to change of the mutual magnetization direction.
[0017] The sensing section of the magnetic head of this operation gestalt is the portion of the magneto-resistive effect film inserted into the 1st electrode and the 2nd electrode. Although this sensing section contains the 1st free layer, an interlayer, and the 2nd free layer, it does not contain the magnetic gap layer, antiferromagnetism layer, and magnetization fixing layer (pin layer) which consist of an insulating material. For this reason, compared with the conventional SV-MR film, narrow-gap-izing is easy for the magnetic head of this operation gestalt, and it can respond to high recording density-ization.
[0018] The following structures are applied in order to give a magnetic anisotropy towards a request in the 1st free layer and the 2nd free layer.
[0019] the [ for example, ] — the [ 1 free layer, the middle class, and ] — the both ends of the magneto-resistive effect film formed in 2 free layers — one pair of hard bias films — preparing — the — the [ 1 free layer and ] — the magnetic anisotropy of an one direction may be substantially given to 2 free layers.
[0020] Moreover, by preparing one pair of antiferromagnetism layers in contact with the both ends of the 1st free layer, and fixing magnetization of the both ends of the 1st free layer the — the direction of a request in the center section of 1 free layer — a magnetic anisotropy — giving — the — the both ends of 2 free layers — touching — one pair of antiferromagnetism layers — preparing — the — fixing magnetization of the both ends of 2 free layers — the — a magnetic anisotropy may be given towards a request in the center section of 2 free layers. In this case, it is desirable that the direction of the magnetic anisotropy of the 1st free layer center section and the direction of the magnetic anisotropy of the 2nd free layer center section make the angle of about 90 degrees. However, what is necessary is for the range of the angle which the direction of the magnetic anisotropy given to two free layers makes just to be 60 degrees - 120 degrees.
[0021] Thus, the 1st free layer and the 2nd free layer to which the magnetic anisotropy was given change the magnetization direction independently according to the signal magnetic flux from data medium, and demonstrate a magneto-resistive effect according to change of the mutual magnetization direction. Consequently, the magnetic head concerning the operation gestalt of this invention can read the information recorded on data medium. In addition, although data-medium magnetic flux is detected by different principle according to the method of grant of the magnetic anisotropy to the 1st free layer and the 2nd free layer which were mentioned above, the detection principle is later explained to details.
[0022] A free layer is formed with the ferromagnetic material containing the metal layers which consist of Co, Fe, and nickel, or those alloy layers. More specifically, the ferromagnetic materials used for a free layer are $Co_{90}Fe_{10}$ (at%), CoFeNi, NiFe, Fe, Co, nickel, etc.
[0023] in order to take out the effect of spin dependence dispersion in the interior of a free layer — the — the [ 1 free layer and ] — it is good also considering 2 free layers as the laminated structure of [a ferromagnetic layer /

ferromagnetic layer], the laminated structures of [a ferromagnetic layer / non-magnetic layer], or these composite constructions.

[0024] Combination, such as [NiFe/CoFe], [Fe/NiFe], and [Fe/CoFe], is used for the laminating free layer of [a ferromagnetic layer / ferromagnetic layer].

[0025] In the case of the laminating free layer of [a ferromagnetic layer / non-magnetic layer], a non-magnetic layer is chosen from noble metals, such as Au, Ag, Cu, Ir, Ru, Rh, Pd, and Pt. As a combination of [the ferromagnetic layer / non-magnetic layer] which increases dispersion by the interface, [NiFe/Au], [NiFe/Ag], [CoFe/Cu], [Co/Cu], [Fe/Au], [nickel/Au], etc. are mentioned.

[0026] Moreover, a Ms-t product (saturation magnetization and thickness product) may be adjusted to a free layer using the ferry coupling free layer (synthetic free layer) which consists of [a magnetic layer / Ru / a magnetic layer].

[0027] In the operation gestalt of this invention, a substrate layer and a protective layer are prepared so that the magneto-resistive effect film containing the 1st free layer, an interlayer, and the 2nd free layer may be inserted. The specular reflection layer (speculer layer) for using the stacking tendency control layer and the electronic specular reflection effect of raising the crystal stacking tendency of metal layers, such as Ta, the soft magnetism substrate layer which raises the soft magnetic characteristics of a free layer, and a free layer, as a substrate layer or a protective layer is used. nickel80Fe20 (at%) alloy (permalloy), amorphous CoZrNb, etc. are contained in a soft magnetism substrate layer. [Ru/Cu], [Au/Cu], Cu, a NiFeCr alloy, etc. are contained in a stacking tendency control layer. It is indicated by the soft magnetism substrate layer and the orientation control layer at U.S. Pat. No. 5,549,978. undercoating film A material can also be used. Cr oxide;Mn oxides, such as Fe oxide;Ta oxide;nickel oxide;Cr(s) 2O3, such as gamma-Fe 2O3 and Fe3O4, and CrO2, etc. are contained in a speculer layer.

[0028] The speculer layer mentioned above can be inserted in a free layer or an interlayer. When a speculer layer or an insulating layer which was mentioned above is inserted into an interlayer, as a nonmagnetic conductivity interlayer, as for the case of Cr oxide etc., Cu layer etc. is used well. As for the thickness of the nonmagnetic conductivity interlayer at this time, it is desirable that it is 1nm or less. A nonmagnetic conductivity interlayer may form only in one side of an insulator layer. By existence of a nonmagnetic conduction layer, the soft magnetic characteristics of the 1st and 2nd free layer improve.

[0029] In this operation gestalt, it is desirable to install a magneto-resistive effect film between one pair of magnetic shielding. if a magneto-resistive effect film is installed between one pair of magnetic shielding — output peak-mesial-magnitude width of face (PW50) — small — it can stop — a still better line — resolution can be obtained.

[0030] In this case, it is desirable to connect each of one pair of magnetic shielding to the 1st electrode or the 2nd electrode, and an electric target. With such a configuration, an electrode and a shield can be dealt with as an electrode in one, the polar zone is formed into low resistance, and the effect of the heat to a CPP-MR film can be reduced.

[0031] in addition, the magnetic head concerning the operation gestalt of this invention — setting — one pair of magnetization free layers (free layer) — a magnetic circuit — forming — an interlayer's (spacer layer) thickness — a line — a shield can be omitted when specifying the magnetic gap which determines resolution.

[0032] The conductive non-magnetic material chosen from the group which consists of Be, aluminum, Mg, calcium, Cu, Au, Ag, Rh, Ru, and Ir is used for an interlayer. If such a conductive non-magnetic material is used, sufficiently long spin diffusion length about 50nm or more can be obtained, and big spin dependence dispersion can be acquired by the interface between a free layer and an interlayer.

[0033] An interlayer is good also as a three-tiered structure including one pair of 1st interlayers who touch the 1st magnetization free layer or the 2nd magnetization free layer, respectively, and the 2nd interlayer formed so that it might be inserted into one pair of 1st interlayers. In this case, it is desirable to form the 1st interlayer with at least one sort of metals chosen from the group which consists of Cu, Au, Ag, Rh, Ru, and Ir, and to form the 2nd interlayer with at least one sort of metals chosen from the group which consists of Be, aluminum, Mg, and calcium. The 1st above-mentioned interlayer shows big spin dependence dispersion according to the interface between a free layer and an interlayer. The 2nd above-mentioned interlayer shows long spin diffusion length.

[0034] An oxide layer may be used for an interlayer in other operation gestalten of this invention. In this case, a magneto-resistive effect film is a tunnel mold magneto-resistive effect film containing the 1st free layer, an oxide interlayer, and the 2nd free layer. At least one layer chosen from the group which consists of the aluminum oxide 2O3, for example, aluminum, the Si oxide 2, for example, SiO, Ta oxide, the Cr oxide 2, for example, CrO, a Fe oxide 3O4, for example, Fe, and a perovskite mold oxide (LSMO), for example, LaSrMnO, is used for an oxide layer. When element resistance of a tunnel mold magneto-resistive effect film is taken into consideration, as for an interlayer's thickness, it is desirable to make it about 5nm or less.

[0035] In other operation gestalten of this invention, you may form in the middle class by the sandwiches film of the cascade screen of [a metal layer / oxide layer, or a CHITSU ghost layer], [a metal layer / oxide layer / metal layer], or a [a metal layer / CHITSU ghost layer / metal layer]. In this case, at least one layer chosen from the group which consists of the aluminum oxide 2O3, for example, aluminum, the Si oxide 2, for example, SiO, Fe oxide, Ta oxide, nickel oxide, a perovskite mold oxide, and a Cr oxide is used for the above-mentioned oxide layer. In this case, at least one layer chosen from the group which consists of Cu, Ru, Ag, Au, Ir, and Rh is used for the above-mentioned metal layer. The above-mentioned metal layer controls and prevents oxidation of a free layer. Consequently, the soft magnetic characteristics of a free layer improve and low coercive force is acquired in each free layer.

[0036] Hereafter, the operation gestalt of this invention is explained more to details, referring to a drawing. (1st

operation gestalt) Drawing 1 (a) is the cross section which cut the perpendicular energization mold magneto-resistive effect (CPP-MR) arm head in the 1st operation gestalt in respect of being perpendicular to a data-medium opposed face (ABS:air-bearing surface). In x, in this drawing, z shows [ as opposed to / in the direction of truck length, and y / a data-medium opposed face ] a perpendicular direction as opposed to the truck cross direction. This CPP-MR head is used for a vertical-magnetic-recording system.
[0037] As shown in drawing 1 (a), this CPP-MR head has the structure which carried out the laminating of the lower magnetic shielding 21, the 1st electrode 22, the substrate layer 31, the 1st magnetization free layer (the 1 free layer) 23, the spacer layer 24 formed by the conductive non-magnetic material, the 2nd magnetization free layer (the 2 free layers) 25, a protective layer 32, the 2nd electrode 26, and the up magnetic shielding 27 one by one.
[0038] The film surface of the 1st free layer 23 which constitutes a CPP-MR film, the 2nd free layer 25, and the spacer layer 24 pinched by them is almost perpendicular to the data-medium opposed face. According to the signal magnetic flux by which the 1st free layer and the 2nd free layer are recorded on magnetic-recording data medium, magnetization answers freely. Magnetic-reluctance change occurs with the angle which the magnetization direction of the 1st free layer 23 and the 2nd free layer 25 makes, and data-medium magnetic flux can be read so that it may mention later.
[0039] the [ the 1st electrode 22, the substrate layer 31, and ] -- the [ 1 free layer 23, the spacer layer 24, and ] -- the insulator layer 28 is formed in the location distant from ABS of 2 free layers 25, a protective layer 32, and the 2nd electrode 26 in the direction of z. Current is passed by the CPP-MR film at right angles to a film surface with the 1st electrode 22 and the 2nd electrode 26. The metal or alloy mainly chosen from Cu, Au, Ag, and Ta is used for the material of these electrodes. this CPP-MR head -- the existence of magnetic shielding -- not being concerned -- a good line -- since resolution is obtained, it is not necessary to necessarily prepare magnetic shielding however, the direction in which magnetic shielding 21 and 27 was formed -- a line -- since resolution can be improved more, it is desirable.
[0040] Drawing 1 (b) is the plan which looked at the CPP-MR film portion of the CPP-MR head shown in drawing 1 (a) from ABS. The CPP-MR film containing the 1st free layer 23, the spacer layer 24, and the 2nd free layer 25 is installed between one pair of hard bias films (hard film) 29 and 30. As for the 1st free layer 23 and the 2nd free layer 25, a bias magnetic field is impressed so that a magnetic anisotropy may be given to an one direction by the hard films 29 and 30.
[0041] The output device of the CPP-MR head of this operation gestalt is explained. Drawing 2 (a) - (c) is a mimetic diagram explaining change of the magnetization direction of the magneto-resistive effect film to data-medium magnetic flux. These drawings indicate the vertical recording layer 1 to be MR film containing the 1st free layer 23, the spacer layer 24, and the 2nd free layer 25 along the direction of truck length. Drawing 2 (a) shows the case where it runs the upper part of a record magnetic domain where in drawing 2 (b), as for drawing 2 (c), down magnetization continues [ an arm head ] when an arm head runs the upper part of the transition region of rise magnetization and down magnetization, when an arm head runs the upper part of a record magnetic domain where rise magnetization continues.
[0042] Drawing 2 (a) According to change of the relative location to data medium of MR film shown in - (c), the magnetization direction of the 1st free layer and the 2nd free layer changes as follows according to the direction of the record magnetization in data medium. As shown in drawing 2 (a), when rise magnetization continues in data medium, magnetization of the 1st free layer and the 2nd free layer becomes parallel to the sense and each other in both the rise directions. As shown in drawing 2 (b), in the transition region of data-medium magnetization, magnetization of the 1st free layer by the side of leading changes in the down direction, and magnetization of the 2nd free layer by the side of trailing does not change with the rise direction. Therefore, the magnetization direction of the 1st and 2nd free layers becomes anti-parallel mutually. As shown in drawing 2 (c), when down magnetization continues in data medium, magnetization of the 1st free layer and the 2nd free layer becomes parallel to the sense and each other in both the down directions.
[0043] The output wave (deltaV=I-deltarho) of the CPP-MR head of this operation gestalt is typically shown in drawing 3 . The output value shown by (a) in drawing 3 , (b), and (c) supports the condition of drawing 2 (a), (b), and (c), respectively.
[0044] The output wave shown in drawing 3 is almost the same as what is obtained by the magnetic-recording system within a field which used the conventional MR head. Therefore, it is possible to sense record magnetization, without changing the circuit and system of the regenerative-signal processing section in a magnetic-recording regeneration system.
[0045] Drawing 4 is drawing explaining the principle from which the output wave shown in drawing 3 is acquired. This drawing supports drawing 2 (b) and magnetization of the 1st free layer and magnetization of the 2nd free layer are making the angle theta.
[0046] here -- the -- the [ 1 free layer and ] -- rhoAP and the maximum resistance variation are set to deltarhomax for the electric resistance at the time of being rhoP and anti-parallel about the electric resistance of a magneto-resistive effect film when the magnetization direction of 2 free layers is parallel. At this time, resistance change deltarho is expressed with a degree type using the angle theta of drawing 4 which the magnetization direction of the 1st free layer and the 2nd free layer makes.
[0047]
deltarho=deltarhomax-cos(theta/2) = (rhoAP-rhoP), cos (theta/2) (1)
In addition, delta rho=rho P-MR can also express deltarho using MR rate-of-change:MR=(rhoAP-rhoP)/rhoP.

[0048] Therefore, output change deltaV is expressed with a degree type.
[0049]
delta V=I-delta rho=I -(rhoAP-rhoP)- cos (theta/2) (2)
(2) deltaV is obtained by only the movement toward magnetization of the 1st and 2nd free layer as shown in a formula. However, the movement toward magnetization of a free layer is dependent also on distribution of data-medium magnetic flux in fact.
[0050] When designing a CPP-MR head, it becomes important to set up appropriately the coercive force (Hc) of a data-medium film, the transition length on data medium (TL), the distance between magnetic data medium and an arm head (MS), the half-value width (illustrated by PW50 and drawing 6 ) of a pulse, and the thickness (tspacer) of a spacer layer.
[0051] The thickness of a spacer layer is determined by the spin diffusion length within a spacer layer. Since output pulse width of face will spread if the thickness of a spacer layer becomes thick, it is not desirable. On the contrary, if the thickness of a spacer layer becomes thin, the magnetic-flux suction effectiveness of an MR head will fall. In order to improve magnetic-flux suction effectiveness, it is necessary to set up the dimension of a CPP-MR film appropriately.
[0052] The parameter of the CPP-MR head in the 1st operation gestalt and a record medium is shown in drawing 5 (a). Here, as shown in drawing 5 (a), thickness of mu and a spacer layer is set [ the depth (depth) of a CPP-MR element / the attenuation length of D and magnetic flux / the thickness of FD and a free layer ] to tspacer for the permeability of tfree1=tfree2=tf and a free layer. At this time, the attenuation length of the magnetic flux in the CPP-MR head which has not prepared the shield is given by the degree type.
[0053]
[Equation 1]

$$FD = \sqrt{\frac{\mu \cdot tf \cdot t_{spacer}}{2}} \qquad (3)$$

[0054] According to our research, the thickness of a spacer layer is understood that it is desirable that they are [ 2nm or more ] 50nm or less and 5 morenm or more 30nm or less. Magnetic-flux suction effectiveness falls that the thickness of a spacer layer is less than 2nm, and an output declines. If the thickness of a spacer layer is larger than 50nm, MR rate of change will fall.
[0055] The thickness of a spacer layer is given by the degree type from a formula (3).
[0056]
[Equation 2]

$$t_{spacer} = \frac{2 \cdot FD^2}{\mu \cdot tf} \qquad (4)$$

Therefore, it is desirable for the right-hand side of a formula (4) to fill the following relation.
[0057]
[Equation 3]

$$2(\mathrm{nm}) \leq \frac{2 \cdot FD^2}{\mu \cdot tf} \leq 50(\mathrm{nm}) \qquad (5)$$

[0058] Since it is set to mu= 100 and tf=2nm-10nm in the case of the recording density of 100 or more Gbpsis, attenuation length FD becomes 14(nm) <=FD<=160(nm).
[0059] In order to raise magnetic-flux effectiveness, as for the depth D of MR film, it is desirable that it is larger than attenuation length FD, and it is desirable to fulfill the conditions of D>=FD. In this case, only the depth of a free layer may be lengthened. Moreover, the effect of improving magnetic-flux effectiveness effectually like the case where did not lengthen the depth D of MR film but the depth D of MR film is lengthened also by forming the posterior part flux guide 33 in the posterior part of the MR film 20 as illustrated to drawing 5 (b) is acquired. In this case, when the length of the posterior part flux guide 33 is set to GD, it is desirable to fulfill the conditions of D+GD>=FD. Therefore, it is desirable that it is D>=160nm or D+GD>=160nm in the recording density of 100 or more Gbpsis.
[0060] Next, the example which estimated concretely the output at the time of using the CPP-MR head shown in drawing 5 (a) is explained.
[0061] About the CPP-MR film, NiFe/CoFe was used for the 1st and 2nd free layers 23 and 25, Cu was used for the spacer layer 24, and it considered as a length of L= 100nm of thickness tspacer=20nm of 2= 5nm of thickness tfree1=tfree(s) of a free layer, and a spacer layer, D= 100nm of depths, and the truck cross direction. They could be thickness tbias=40nm of a hard bias film, and residual magnetization Mrbias=500emu/cc at the hard bias films 29 and 30 (magnetization has fixed to the one direction) using the CoCrPt film. Data medium is the laminated structure of the vertical recording layer 1 and the soft magnetism backing layer 2, and was set to thickness trecord=10nm of a record layer, residual magnetization Mrrecord=400emu/cc, and thickness tsoft=10nm of a backing layer. Transition of the magnetization between bits was assumed with the tanh mold, and could be transition length TL=10nm. a CPP-MR head and data medium are magnetic — it could be spacing MS=10nm.
[0062] The output wave acquired by drawing 6 on condition that the above is shown. In drawing 6 , (a) is [ those with a shield (shield gap: 70nm) and (c of shield nothing and (b)) ] with a shield (shield gap: 50nm). PW50 which is the

half-value width of an output becomes small as are shown in drawing 6 and a shield gap becomes narrow. In addition, although the peak value of an output also falls, it is a satisfactory degree as a shield gap becomes narrow.
[0063] (2nd operation gestalt) Drawing 7 is the cross section which cut the CPP-MR head in the 2nd operation gestalt in respect of being parallel to a data-medium opposed face. An insulating layer 42 is formed on the lower shield 41, the part is etched, and the 1st electrode 43 of the pillar configuration which touches the lower shield 41 is embedded there. The 1st 1 to antiferromagnetism layer 44a and 44b by which patterning was carried out is formed on the both-sides section of an insulating layer 42 along the truck cross direction (the direction of y) centering on the 1st electrode 43. The substrate layer 55 is formed on the 1st electrode 43, an insulating layer 42 and antiferromagnetism layer 44of ** 1st a, and 44b. On the substrate layer 55, the CPP-MR film containing the 1st free layer 45, the spacer layer 46, and the 2nd free layer 47 is formed. the -- a part of 2 free layers 47 -- the protective layer 57 is formed upwards. the truck cross direction (the direction of y) -- meeting -- the -- the both-sides section of 2 free layers 47 is touched, and the 2nd 1 to antiferromagnetism layer 48a and 48b by which patterning was carried out is formed. An insulating layer 49 is formed on a protective layer 57 and antiferromagnetism layer 48of ** 2nd a, and 48b, the part is etched, and the 2nd electrode 50 of the pillar configuration which touches the 2nd free layer 47 is embedded there. The up shield 51 is formed on an insulating layer 49 and the 2nd electrode 50.
[0064] The material same with having explained in the 1st operation gestalt can be used for a free layer and a spacer layer.
[0065] As a material of a substrate layer and a protective layer, soft magnetic materials [ and ] (permalloy), for example, NiFe, such as non-magnetic metal, for example, Ta, Ti, Cu, Ru, Au, Cr, etc., amorphous CoZrNb, etc. are mentioned.
[0066] As an antiferromagnetism layer, a PtMn alloy, a PtPdMn alloy, a CrMn alloy, a CrPtMn alloy, an IrMn alloy, a RhMn alloy, etc. are used. The pattern of an antiferromagnetism layer can form the following methods. (i) A resist is removed, after forming the antiferromagnetic substance, carrying out patterning of the resist according to a photolithography process and forming the pattern of an antiferromagnetism layer by ion milling by using a resist as a mask. (ii) After carrying out patterning of the resist with photolithography, removing the protective layer on a free layer and forming the antiferromagnetic substance, the pattern of an antiferromagnetism layer may be formed by removing a resist and the antiferromagnetic substance on it by lift off.
[0067] SiO2, aluminum 2O3, etc. are used for the insulating layer formed between an antiferromagnetic substance layer and an electrode. In addition, to a free layer, an antiferromagnetism layer does not necessarily need to form an insulating layer, when specific resistance is large enough. Although what is necessary is just to form to one of electrodes at least in forming an insulating layer, forming to both electrodes is still more desirable. The size of the contact section of a free layer and an electrode is prescribed by opening of an insulating layer. [0068] Also in this CPP-MR head, the sensing section is the portion of the CPP-MR film inserted into the 1st electrode 43 and the 2nd electrode 50. This sensing section contains the 1st free layer 45, the spacer layer 46, and the 2nd free layer 47. On the other hand, the antiferromagnetism layers 44a, 44b, 48a, and 48b by which patterning was carried out are removed and formed from the sensing section. Therefore, a narrow gap is realizable by this CPP-MR head as well as the 1st operation gestalt.
[0069] the 1st antiferromagnetism layer 44a and 44b -- the -- the [ which is equivalent to the sensing section (center section of the drawing) by fixing magnetization of the both ends of 1 free layer 45 ] -- a magnetic anisotropy is given in the direction which makes a predetermined angle to a data-medium opposed face in 1 free layer 44. the same -- the 2nd antiferromagnetism layer 48a and 48b -- the -- the [ which is equivalent to the sensing section (center section of the drawing) by fixing magnetization of the both ends of 2 free layers 47 ] -- a magnetic anisotropy is given in the direction which makes a predetermined angle to a data-medium opposed face in 2 free layers 47. the -- the [ 1 free layer 45 and ] -- as for the direction of the magnetic anisotropy given to 2 free layers 47, it is desirable to measure from a data-medium opposed face and to make about 45 degrees into the direction which intersects perpendicularly mostly nothing and mutually. However, what is necessary is for the range of the angle which the direction of the magnetic anisotropy given to two free layers makes just to be 60 degrees - 120 degrees about.
[0070] Specifically, annealing gives a magnetic anisotropy to a free layer using the switched connection of an antiferromagnetism layer and a free layer. For this reason, two steps of annealing is performed so that a magnetic anisotropy may be given to the 1st free layer 45 and the 2nd free layer 47, respectively. At this time, between the 1st antiferromagnetism layer 44a and 44b and the 2nd antiferromagnetism layer 48a and 48b, thickness is changed, or a presentation is changed and the temperature characteristic of blocking temperature and a switched connection magnetic field is adjusted so that the magnetic anisotropy given to the 1st free layer 45 may not be influenced by the 2nd-step annealing.
[0071] When controlling the magnetic anisotropy of a free layer by one pair of antiferromagnetism layers by which patterning was carried out to be shown in drawing 7 , it is desirable to set up appropriately the distance L between two antiferromagnetic substance layers. As for the distance L between two antiferromagnetic substance layers, it is desirable that it is 0.5 micrometers or less. If L is larger than 0.5 micrometers, it will become difficult to control the magnetic anisotropy of the free layer located between two antiferromagnetism layers, it will make a free layer generate big coercive force, and will cause a Barkhausen noise further. Moreover, since it is generally said that spin bond length is 0.2 micrometers or less, as for L, it is still more desirable that it is 0.2 micrometers or less.
[0072] Next, the principle of operation of the CPP-MR head of this operation gestalt is explained. In order to detect data-medium magnetic flux by the magnetic head of this operation gestalt, two methods shown below are used.

[0073] With reference to drawing 8 and drawing 9 , the 1st method for detecting data-medium magnetic flux is explained.
[0074] Drawing 8 is drawing showing an example of the direction of the magnetic anisotropy given to one pair of free layers in the CPP-MR head of drawing 7 . In order to make an understanding easy, the 1st free layer 45 and the 2nd free layer 47 are lined up side-by-side, and this drawing shows them. However, the 1st free layer 45 and the 2nd free layer 47 have lapped in fact. In the direction of the magnetic anisotropy of about +45-degree slanting facing up and the 2nd free layer 47, in drawing 8 , the direction of the magnetic anisotropy of the 1st free layer 45 serves as -45 degree slanting facing up of abbreviation to the data-medium confrontation side to the data-medium confrontation side. Therefore, the direction of the magnetic anisotropy of the 1st free layer 45 and the direction of the magnetic anisotropy of the 2nd free layer 47 lie at right angles mostly.
[0075] Drawing 9 is drawing showing the output wave by the CPP-MR head which has one pair of free layers to which the magnetic anisotropy was given like drawing 8 .
[0076] the case where an arm head runs the upper part of a record magnetic domain where rise magnetization continues — the — the [ the magnetization direction of 1 free layer 45, and ] — since the magnetization direction of 2 free layers 47 becomes parallel mutually toward both the rise directions, output voltage shows the minimum value called -Vpp.
[0077] Since the magnetization direction of the 1st free layer 45 and the magnetization direction of the 2nd free layer 47 have intersected perpendicularly mostly when an arm head runs the upper part of a magnetization transition region, output voltage is about 0.
[0078] the case where an arm head runs the upper part of a record magnetic domain where down magnetization continues — the — the [ the magnetization direction of 1 free layer 45, and ] — since the magnetization direction of 2 free layers 47 is level and becomes anti-parallel mutually, output voltage shows a peak price called +Vpp.
[0079] By detecting signal magnetic flux as mentioned above, the magnetization direction of the record bit of a record medium is directly detectable. the case where this principle of operation is used — magnetic flux — the — the [ 1 free layer 45 or ] — since it flows from 2 free layers 47 to the lower shield 41 or the up shield 51, it is necessary to prepare one pair of magnetic shielding
[0080] With reference to drawing 10 and drawing 11 , the 2nd method for detecting data-medium magnetic flux is explained.
[0081] Drawing 10 is drawing showing other examples of the direction of the magnetic anisotropy given to one pair of free layers in the CPP-MR head of drawing 7 . In the direction of the magnetic anisotropy of about +45-degree slanting facing up and the 2nd free layer 47, in drawing 10 , the direction of the magnetic anisotropy of the 1st free layer 45 serves as -45 degree slanting facing down of abbreviation to the data-medium confrontation side to the data-medium confrontation side. Therefore, the direction of the magnetic anisotropy of the 1st free layer 45 and the direction of the magnetic anisotropy of the 2nd free layer 47 lie at right angles mostly.
[0082] Drawing 11 is drawing showing the output wave by the CPP-MR head which has one pair of free layers to which the magnetic anisotropy was given like drawing 10 .
[0083] the case where an arm head runs the upper part of the transition region to the rise magnetization from down magnetization — the — the [ the magnetization direction of 1 free layer 45, and ] — since both the magnetization directions of 2 free layers 47 are level and become parallel, output voltage shows the minimum value called -Vpp.
[0084] Since the magnetization direction of the 1st free layer 45 and the magnetization direction of the 2nd free layer 47 have intersected perpendicularly mostly when an arm head runs the upper part of a record magnetic domain where rise magnetization or down magnetization continues, output voltage is about 0.
[0085] When an arm head runs the upper part of the transition region to the down magnetization from rise magnetization, the magnetization direction of facing up and the 2nd free layer 47 is downward, and since it becomes anti-parallel mutually, as for the magnetization direction of the 1st free layer 45, output voltage shows a peak price called +Vpp.
[0086] By detecting signal magnetic flux as mentioned above, the transition region of a record bit is detectable. the case where this principle of operation is used — magnetic flux — the — the [ from 1 free layer 45 ] — the [ 2 free layers 47 or ] — the [ from 2 free layers 47 ] — since it flows to 1 free layer 45, it is not necessary to necessarily prepare one pair of magnetic shielding
[0087] (Other operation gestalten) Drawing 12 is the cross section which cut the CPP-MR film used for the CPP-MR head of other operation gestalten in respect of being perpendicular to a data-medium opposed face. The laminating of the substrate layer 31, the 1st free layer 23, the spacer layer 24, the 2nd free layer 25, and the protective layer 32 is carried out by the CPP-MR film of drawing 12 like drawing 1 (a). however — the CPP-MR film of drawing 12 — the spacer layer 24 — respectively — the — the [ 1 free layer 23 or ] — it has a three-tiered structure containing 2nd spacer layer 24b formed so that it might be inserted into 1 pair of 1st spacer layer 24a which touches 2 free layers, and 1 pair of 1st spacer layer 24a.
[0088] As mentioned above, the thickness of a spacer layer is very important when designing the CPP-MR head concerning the operation gestalt of this invention. Therefore, also in order to increase the flexibility of layout, it is desirable to choose the material which can set spin diffusion length to a spacer layer long enough.
[0089] An alloy which contains the metal or them which spin diffusion length becomes from an element with small atomic weight like aluminum, Mg, Be, and calcium as a long material is mentioned. The spin diffusion length of aluminum, Mg, Be, and calcium is about 200nm at a room temperature. Therefore, it is appropriate to use aluminum or Mg layer for a part of spacer layer. Moreover, materials, such as Cu, Au, Ag, Rh, Ru, Ir, etc. with low conductivity,

are also long, and its spin diffusion length is desirable as a material of a spacer layer. With these materials, it is thought as a result of our research that there is 50nm or more of spin diffusion length.

[0090] As a desirable laminated structure, the three-tiered structure of [the 1st spacer layer / the 2nd spacer layer / the 1st spacer layer] is mentioned especially. The metal chosen from Au, Cu, Ag, Rh, Ir, and Ru is used for the 1st spacer layer. The metal chosen from aluminum, Mg, Be, and calcium is used for the 2nd spacer layer. In this laminated structure, the 2nd spacer layer adjusts spin diffusion length, and the effect of spin dependence dispersion is given in an interface with the 1st spacer layer, the 1st free layer, or the 2nd free layer.

[0091] In order to lengthen spin diffusion length as much as possible, as for the thickness of the 1st spacer layer, it is desirable that it is 10nm or less. As for the thickness of the 2nd spacer layer, it is desirable that it is 200nm or less so that it may become shorter than spin diffusion length.

[0092] Moreover, when the spin diffusion length in a free layer also takes into consideration, as for the sum total of the thickness of the free layer of a CPP-MR film, and a spacer layer, it is desirable that he is 50% or less of the spin diffusion length of the 2nd spacer layer. Here, the thickness of a free layer means the thickness of the portion which contributes to spin dependence dispersion. That is, in the case of a simple free layer, in the case of all thickness and a synthetic free layer, the thing of the thickness which totaled the thickness of Ru layer and the thickness of the magnetic layer by the side of a spacer layer is pointed out.

[0093] The magneto-resistive effect film shown in drawing 13 or drawing 14 can also be used for the magneto-resistive effect arm head concerning other operation gestalten of this invention.

[0094] Drawing 13 is the cross section of the tunnel mold magneto-resistive effect film (TMR) which carried out the laminating of the spacer layer 62 and the 2nd free layer 63 which were formed with oxides, such as the 1st free layer 61 and aluminum 2O3. When element resistance is taken into consideration by the TMR film, as for the thickness of the spacer layer 62, it is desirable that it is 5nm or less. At least one layer chosen from perovskite mold oxides, such as Fe oxides, such as aluminum oxides, such as aluminum 2O3, and Fe 3O4, and LSMO, can be used for the spacer layer 62.

[0095] Although drawing 14 is a TMR film which has the same structure as drawing 13 , the layered product of [CHITSU ghost layer 62b / metal layer 62a / oxide layer, or metal layer 62a] is used for it as a spacer layer 62. A middle oxide layer or CHITSU ghost layer 62b does not necessarily need to be a continuation film, and may be discontinuous. It can check whether oxide layer or CHITSU ghost layer 62b is a continuation film by electron microscope observation.

[0096] Next, the magnetic-head assembly which carried the CPP-MR head concerning this invention, and the magnetic disk drive which carried this magnetic-head assembly are explained.

[0097] Drawing 15 (a) is the perspective diagram of a magnetic-head assembly which carried the CPP-MR head. An actuator arm 201 has the bobbin section which the hole for being fixed to the fixed shaft in a magnetic disk drive is prepared, and holds the drive coil which is not illustrated. The suspension 202 is being fixed to the end of an actuator arm 201. The head slider 203 which carried the CPP-MR head is attached at the tip of a suspension 202. Moreover, the writing of a signal and the lead wire 204 for reading are wired in a suspension 202, the end of this lead wire 204 is connected to each electrode of the CPP-MR head included in the head slider 203, and the other end of lead wire 204 is connected to the electrode pad 205.

[0098] Drawing 15 (b) is the perspective diagram showing the internal structure of the magnetic disk drive which carried the magnetic-head assembly shown in drawing 15 (a). A spindle 212 is equipped with a magnetic disk 211, and it rotates by the motor which answers a control signal from the driving gear control section which is not illustrated and which is not illustrated. It is fixed to the fixed shaft 213 and the actuator arm 201 is supporting the suspension 202 and the head slider 203 at the tip. If a magnetic disk 211 rotates, the data-medium opposed face of the head slider 203 will be held where specified quantity surfacing is carried out from the surface of a magnetic disk 211, and will perform informational record playback. The voice coil motor 214 which is one sort of a linear motor is formed in the end face of an actuator arm 201. A voice coil motor 214 consists of magnetic circuits which consist of the permanent magnet and opposite yoke which have been countered and arranged so that the drive coil which was able to be wound up in the bobbin section of an actuator arm 201, and which is not illustrated, and this coil may be put. An actuator arm 201 is held by the ball bearing which was prepared in two upper and lower sides of the fixed shaft 213 and which is not illustrated, and has come to be able to perform a rotation slide free with a voice coil motor 214.

[0099]

[Effect of the Invention] As explained above, according to this invention, narrow gap-ization is attained and the magneto-resistive effect arm head which can respond to high recording density-ization, and the magnetic recorder and reproducing device which has this magneto-resistive effect arm head can be offered.

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[Translation done.]

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The cross section which cut the perpendicular energization mold magneto-resistive effect (CPP-MR) arm head in the 1st operation gestalt in respect of being perpendicular to a data-medium opposed face, and the plan which looked at the CPP-MR film of this CPP-MR head from the data-medium opposed face.
[Drawing 2] The mimetic diagram for explaining change of the magnetization direction of the magneto-resistive effect film to data-medium magnetic flux about the CPP-MR head in the 1st operation gestalt.
[Drawing 3] Drawing showing typically the output wave of the CPP-MR head in the 1st operation gestalt.
[Drawing 4] Drawing for explaining the principle from which the output wave shown in drawing 3 is acquired.
[Drawing 5] For (a), (b) is drawing showing the parameter of the CPP-MR head in the 1st operation gestalt, and a record medium, and drawing showing the condition of having prepared the posterior part flux guide in the CPP-MR head in the 1st operation gestalt.
[Drawing 6] Drawing showing the output wave acquired on condition that drawing 5 (a).
[Drawing 7] The cross section which cut the CPP-MR head in the 2nd operation gestalt in respect of being parallel to a data-medium opposed face.
[Drawing 8] Drawing showing an example of the direction of the magnetic anisotropy given to one pair of free layers in the CPP-MR head of drawing 7 .
[Drawing 9] Drawing showing the output wave by the CPP-MR head which has one pair of free layers to which the magnetic anisotropy was given as shown in drawing 8 .
[Drawing 10] Drawing showing other examples of the direction of the magnetic anisotropy given to one pair of free layers in the CPP-MR head of drawing 7 .
[Drawing 11] Drawing showing the output wave by the CPP-MR head which has one pair of free layers to which the magnetic anisotropy was given as shown in drawing 10 .
[Drawing 12] The cross section of the CPP-MR film in other operation gestalten.
[Drawing 13] The cross section of the TMR film in other operation gestalten.
[Drawing 14] The cross section of the TMR film in other operation gestalten.
[Drawing 15] The perspective diagram of a magnetic-head assembly which carried the CPP-MR head concerning 1 operation gestalt of this invention, and the perspective diagram showing the internal structure of a magnetic disk drive.
[Drawing 16] The schematic diagram showing the structure of the conventional SV-MR head.
[Drawing 17] Drawing showing the output wave acquired by SV-MR head.
[Description of Notations]
1 — Vertical recording layer
2 — Soft magnetism backing layer
10 — SV-MR film
11 — Antiferromagnetism layer
12 — Pin layer
13 — Spacer layer
14 — Free layer
15 16 — Magnetic shielding
21 — Lower magnetic shielding
22 — The 1st electrode
23 — The 1st magnetization free layer (the 1 free layer)
24 — Nonmagnetic interlayer (spacer layer)
25 — The 2nd magnetization free layer (the 2 free layers)
26 — The 2nd electrode
27 — Up magnetic shielding
28 — Insulator layer
29 30 — Hard bias film (hard film)
31 — Substrate layer
32 — Protective layer
33 — Posterior part flux guide
41 lower shield

42 insulating layers
The 43 1st electrode
44a and 44b — the 1st antiferromagnetism layer
The 45 1st free layers
46 spacer layers
The 47 2nd free layers
48a and 48b — the 2nd antiferromagnetism layer
49 insulating layers
The 50 2nd electrode
51 up shield
55 substrate layers
57 protective layers
The 61 1st free layers
62 spacer layers
62a metal layers
62b oxide layer or a CHITSU ghost layer
The 63 2nd free layers
201 — Actuator arm
202 — Suspension
203 — Head slider
204 — Lead wire
205 — Electrode pad
211 — Magnetic disk
212 — Spindle
213 — Fixed shaft
214 — Voice coil motor

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[Translation done.]

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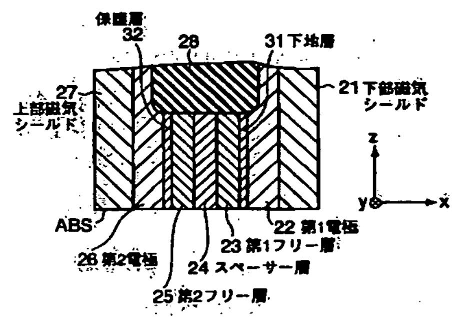
(71)出願人 000003078
株式会社東芝
東京都港区芝浦一丁目１番１号
(72)発明者 吉川 将寿
神奈川県川崎市幸区小向東芝町１番地 株式会社東芝研究開発センター内
(72)発明者 上口 裕三
神奈川県川崎市幸区小向東芝町１番地 株式会社東芝研究開発センター内
(74)代理人 100058479
弁理士 鈴江 武彦 （外６名）

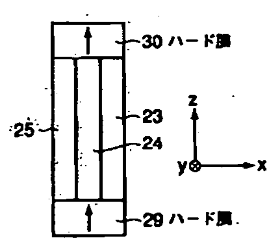
最終頁に続く

(54)【発明の名称】 磁気抵抗効果ヘッドおよび垂直磁気記録再生装置

(57)【要約】
【課題】 高記録密度化に対応して狭ギャップ化が可能な磁気抵抗効果ヘッドを提供する。
【解決手段】 媒体対向面に対して膜面が実質的に垂直に配置された、第１磁化自由層（２３）および第２磁化自由層（２５）と、これらの磁化自由層の間に挟まれた中間層（２４）と、下地層（３１）と、保護層（３２）とを有し、下地層、第１磁化自由層、中間層、第２磁化自由層、保護層の順に順次積層され、第１磁化自由層および第２磁化自由層は媒体からの信号磁束に応じて独立にその磁化方向を変化させ、それぞれの磁化方向の変化に応じて磁気抵抗効果を発揮する磁気抵抗効果膜と、前記磁気抵抗効果膜の膜面に対して実質的に垂直に電流を通電するために設けられ、下地層に電気的に接続された第１電極（２２）および保護層に電気的に接続された第２電極（２７）とを有する磁気抵抗効果ヘッド。



(a)



(b)

効果を利用して媒体磁束を直接感知する磁気抵抗効果ヘッド（MRヘッド）が実用化されてきた。

【0003】現在では、［磁化固着層（ピン層）／中間層（スペーサ層）／磁化自由層（フリー層）］という積層膜を有し、さらに巨大な磁気抵抗効果を発生するスピンバルブ型MR（SV－MR）ヘッドが主流をなしている。このSV－MRヘッドはMRヘッドに比べて２倍以上の巨大磁気抵抗効果を発揮する。

【0004】従来のSV－MRヘッドは、１対の磁気シールドの間に磁気ギャップを介してSV－MR膜を形成した構造を有する。また、従来のSV－MRヘッドは１対の電極からSV膜の面内にセンス電流を通電する、いわゆるCIP（Current-in-plane）－MRヘッドとして使用されてきた。

【0005】最近では、１対の電極からSV膜面に垂直にセンス電流を通電する、いわゆるCPP（Current-perpendicular-to-plane）－MRヘッドが提案されている。CPP通電することによりさらに磁気抵抗変化率（MR変化率）が向上するので、高いヘッド出力が期待できる。

【0006】一方、面内磁気記録システムにおいては、熱擾乱のために記録密度の向上が限界に近づいている。このため、熱擾乱に強い垂直磁気記録システムが有望視され、垂直記録媒体とSV－MRヘッドとを組み合わせたシステムが提案されている。

【0007】図１６（ａ）および（ｂ）は、垂直記録媒体に対して使用することを想定した、すでに提案されているCIPモードのSV－MRヘッドの構造を示す概略図である。図１７（ａ）および（ｂ）は、それぞれ図１６（ａ）および（ｂ）のSV－MRヘッドにより得られる出力波形を示す図である。

【0008】これらのシステムにおいては、出力波形および磁気シールド間の狭ギャップ化が問題となる。すなわち、従来の面内磁気記録システムと同様に、垂直磁気記録システムでも磁化転移でピークを有する出力波形が得られることが好ましい。また、将来の高記録密度化に対応するためには、磁気シールド間に設けられるSV膜の膜厚が薄く、狭ギャップ化を達成できることが好ましい。

【0009】図１６（ａ）は垂直磁気記録システムにシングルSV－MRヘッドを適用したものである。図１６（ａ）において、垂直記録層１に対向するように、１つのSV－MR膜１０が設けられている。SV－MR膜１０は、反強磁性層１１／ピン層１２／スペーサ層１３／フリー層１４を積層した基本構造を有する。SV－MR膜１０は、１対の磁気シールド１５、１６間に配置されている。

【0010】このシステムでは、図１７（ａ）に示されるように、記録ビットに対応して単調に変化する出力波形が得られる。この場合、従来の面内磁気記録システムと同様に磁化転移でピークを有する出力波形を得るためには、再生信号処理部に微分回路を追加しなければならない。しかし、微分回路はノイズを増大させるおそれがある。また、従来のSV－MRヘッドは厚い反強磁性層１１を有するため、将来の高記録密度化に対応して狭ギャップ化することが困難であるという問題があった。

【0011】図１６（ｂ）は垂直磁気記録システムにデュアル・ストライプSV－MRヘッドを適用したものである。図１６（ｂ）において、垂直記録層１に対向するように、１対のSV－MR膜１０が設けられている。各SV－MR膜１０は、図１６（ａ）と同様な基本構造を有する。１対のSV－MR膜１０は、１対の磁気シールド１５、１６間に配置されている。

【0012】このシステムでは、２つのSV－MR膜を差動動作させて、図１７（ｂ）に示されるように従来の面内磁気記録システムで得られるのと同様な出力波形を得るようにしている。しかし、この構造においては、磁気ギャップ中に２つのSV－MR膜が形成されるため、やはり将来の高記録密度化に対応できないという問題があった。

【0013】

【発明が解決しようとする課題】本発明の目的は、高記録密度化に対応して狭ギャップ化が可能な磁気抵抗効果ヘッド、およびこのようなヘッドを搭載した垂直磁気記録再生装置を提供することにある。

【0014】

【課題を解決するための手段】本発明の一態様に係る磁気抵抗効果ヘッドは、媒体対向面に対して膜面が実質的に垂直に配置された、第１磁化自由層および第２磁化自由層と、これらの磁化自由層の間に挟まれた中間層と、下地層と、保護層とを有し、下地層、第１磁化自由層、中間層、第２磁化自由層、保護層の順に順次積層され、前記第１磁化自由層および第２磁化自由層は媒体からの信号磁束に応じて独立にその磁化方向を変化させ、それぞれの磁化方向の変化に応じて磁気抵抗効果を発揮する磁気抵抗効果膜と、前記磁気抵抗効果膜の膜面に対して実質的に垂直に電流を通電するために設けられ、下地層に電気的に接続された第１電極および保護層に電気的に接続された第２電極とを有する。

【0015】本発明の他の態様に係る垂直磁気記録再生装置は、垂直磁気記録媒体と、垂直磁気記録媒体に対向して設けられる上記の磁気抵抗効果ヘッドとを有する。

【0016】

【発明の実施の形態】本発明の実施形態に係る磁気ヘッドは、第１磁化自由層（第１フリー層）および第２磁化自由層（第２フリー層）と、これらのフリー層の間に挟まれた中間層（スペーサ層）と、下地層と、保護層とを含む磁気抵抗効果膜と、磁気抵抗効果膜の膜面に対して実質的に垂直に電流を通電する第１電極および第２電極とを有する。すなわち、この磁気抵抗効果膜は、CPP

き、さらに良好な線分解能を得ることができる。

【0030】この場合、1対の磁気シールドの各々を第1電極または第2電極と電気的に接続することが好ましい。このような構成では、電極およびシールドを一体的に電極として取り扱うことができ、電極部を低抵抗化してCPP－MR膜への熱の影響を低減できる。

【0031】なお、本発明の実施形態に係る磁気ヘッドにおいて、1対の磁化自由層（フリー層）によって磁気回路を形成し、中間層（スペーサ層）の厚さによって線分解能を決定する磁気ギャップを規定する場合には、シールドを省略することができる。

【0032】中間層には、例えばBe、Al、Mg、Ca、Cu、Au、Ag、Rh、RuおよびIrからなる群より選択される導電性非磁性材料が用いられる。このような導電性非磁性材料を用いれば、約50nm以上の十分長いスピン拡散長を得ることができ、フリー層と中間層との間の界面で大きなスピン依存散乱を得ることができる。

【0033】中間層は、それぞれ第1磁化自由層または第2磁化自由層と接する1対の第1中間層と、1対の第1中間層に挟まれるように形成された第2中間層とを含む3層構造としてもよい。この場合、第1中間層をCu、Au、Ag、Rh、RuおよびIrからなる群より選択される少なくとも1種の金属で形成し、第2中間層をBe、Al、MgおよびCaからなる群より選択される少なくとも1種の金属で形成することが好ましい。上記の第1中間層はフリー層と中間層との間の界面で大きなスピン依存散乱を示す。上記の第2中間層は長いスピン拡散長を示す。

【0034】本発明の他の実施形態においては、中間層に酸化物層を用いてもよい。この場合、磁気抵抗効果膜は、第1フリー層、酸化物中間層および第2フリー層を含むトンネル型磁気抵抗効果膜である。酸化物層には、Al酸化物たとえば$Al_2O_3$、Si酸化物たとえば$SiO_2$、Ta酸化物、Cr酸化物たとえば$CrO_2$、Fe酸化物たとえば$Fe_3O_4$、およびペロブスカイト型酸化物たとえばLaSrMnO（LSMO）からなる群より選択される少なくとも1層が用いられる。トンネル型磁気抵抗効果膜の素子抵抗を考慮すると、中間層の厚さは約5nm以下にすることが好ましい。

【0035】本発明の他の実施形態においては、中間層に［金属層／酸化物層またはチッ化物層］の積層膜、または［金属層／酸化物層／金属層］もしくは［金属層／チッ化物層／金属層］のサンドイッチ膜で形成してもよい。この場合、上記の酸化物層には、Al酸化物たとえば$Al_2O_3$、Si酸化物たとえば$SiO_2$、Fe酸化物、Ta酸化物、Ni酸化物、ペロブスカイト型酸化物、およびCr酸化物からなる群より選択される少なくとも1層が用いられる。この場合、上記金属層には、Cu、Ru、Ag、Au、Ir、およびRhからなる群より選択される少なくとも1層が用いられる。上記の金属層は、フリー層の酸化を抑制・防止する。その結果、フリー層の軟磁気特性が向上し、各フリー層で低保磁力が得られる。

【0036】以下、図面を参照しながら本発明の実施形態をより詳細に説明する。（第1の実施形態）図1（a）は第1の実施形態における垂直通電型磁気抵抗効果（CPP－MR）ヘッドを媒体対向面（ABS：air-bearing surface）に垂直な面で切断した断面図である。この図において、xはトラック長方向、yはトラック幅方向、zは媒体対向面に対して垂直な方向を示す。このCPP－MRヘッドは、垂直磁気記録システムに使用される。

【0037】図1（a）に示されるように、このCPP－MRヘッドは、下部磁気シールド21、第1電極22、下地層31、第1磁化自由層（第1フリー層）23、導電性非磁性材料で形成されたスペーサ層24、第2磁化自由層（第2フリー層）25、保護層32、第2電極26、および上部磁気シールド27を順次積層した構造を有する。

【0038】CPP－MR膜を構成する、第1フリー層23と第2フリー層25、およびそれらに挟まれるスペーサ層24の膜面は、媒体対向面に対してほぼ垂直になっている。第1フリー層および第2フリー層は、磁気記録媒体に記録されている信号磁束に従って磁化が自由に応答する。後述するように、第1フリー層23と第2フリー層25の磁化方向のなす角度により磁気抵抗変化が発生し、媒体磁束を読み取ることができる。

【0039】第1電極22、下地層31、第1フリー層23、スペーサ層24、第2フリー層25、保護層32、および第2電極26のABSからz方向に離れた位置には絶縁膜28が設けられている。CPP－MR膜には第1電極22と第2電極26により膜面に垂直に電流が流される。これらの電極の材料には、主にCu、Au、Ag、Taから選択される金属または合金が用いられる。このCPP－MRヘッドでは、磁気シールドの有無に関わらず良好な線分解能が得られるので、必ずしも磁気シールドを設ける必要はない。しかし、磁気シールド21、27を設けた方が、線分解能をより向上できるので好ましい。

【0040】図1（b）は、図1（a）に示すCPP－MRヘッドのCPP－MR膜部分をABSから見た平面図である。第1フリー層23、スペーサ層24および第2フリー層25を含むCPP－MR膜は、1対のハードバイアス膜（ハード膜）29、30の間に設置されている。第1フリー層23および第2フリー層25は、ハード膜29、30により一方向に磁気異方性が付与されるように、バイアス磁界が印加される。

【0041】本実施形態のCPP－MRヘッドの出力機構について説明する。図2（a）～（c）は、媒体磁束

μ＝１００、ｔｆ＝２ｎｍ～１０ｎｍとなるので、減衰長ＦＤは１４（ｎｍ）≦ＦＤ≦１６０（ｎｍ）となる。

【００５９】磁束効率を向上させるためには、ＭＲ膜のデプスＤは減衰長ＦＤよりも大きいことが好ましく、Ｄ≧ＦＤの条件を満たすことが好ましい。この場合、フリー層のデプスのみを長くしてもよい。また、ＭＲ膜のデプスＤを長くするのではなく、図５（ｂ）に図示したようにＭＲ膜２０の後部に後部フラックスガイド３３を設けることによってもＭＲ膜のデプスＤを長くした場合と同様に実効的に磁束効率を向上する効果が得られる。この場合、後部フラックスガイド３３の長さをＧＤとすると、Ｄ＋ＧＤ≧ＦＤの条件を満たすことが好ましい。従って、１００Ｇｂｐｓｉ以上の記録密度では、Ｄ≧１６０ｎｍまたはＤ＋ＧＤ≧１６０ｎｍであることが好ましい。

【００６０】次に、図５（ａ）に示されるＣＰＰ－ＭＲヘッドを用いた場合の出力を具体的に見積もった例を説明する。

【００６１】ＣＰＰ－ＭＲ膜については、第１および第２のフリー層２３、２５にＮｉＦｅ／ＣｏＦｅ、スペーサ層２４にＣｕを用い、フリー層の厚さ$t_{free1}$＝$t_{free2}$＝５ｎｍ、スペーサ層の厚さ$t_{spacer}$＝２０ｎｍ、デプスＤ＝１００ｎｍ、トラック幅方向の長さＬ＝１００ｎｍとした。ハードバイアス膜２９、３０（一方向に磁化が固着されている）にはＣｏＣｒＰｔ膜を用い、ハードバイアス膜の厚さ$t_{bias}$＝４０ｎｍ、残留磁化$Mr_{bias}$＝５００ｅｍｕ／ｃｃとした。媒体は垂直記録層１と軟磁性裏打ち層２の積層構造であり、記録層の厚さ$t_{record}$＝１０ｎｍ、残留磁化$Mr_{record}$＝４００ｅｍｕ／ｃｃ、裏打ち層の厚さ$t_{soft}$＝１０ｎｍとした。ビット間の磁化の遷移はｔａｎｈ型で仮定し、遷移長ＴＬ＝１０ｎｍとした。ＣＰＰ－ＭＲヘッドと媒体の磁気的スペーシングＭＳ＝１０ｎｍとした。

【００６２】図６に上記の条件で得られる出力波形を示す。図６において、（ａ）はシールドなし、（ｂ）はシールドあり（シールド間隔：７０ｎｍ）、（ｃ）はシールドあり（シールド間隔：５０ｎｍ）である。図６に示されるように、シールド間隔が狭くなるにつれて、出力の半値幅である$PW_{50}$は小さくなる。なお、シールド間隔が狭くなるにつれて、出力のピーク値も低下するが問題ない程度である。

【００６３】（第２の実施形態）図７は、第２の実施形態におけるＣＰＰ－ＭＲヘッドを媒体対向面と平行な面で切断した断面図である。下部シールド４１上に絶縁層４２が形成され、その一部がエッチングされ、そこに下部シールド４１に接するピラー形状の第１電極４３が埋め込まれている。第１電極４３を中心として、トラック幅方向（ｙ方向）に沿って絶縁層４２の両側部の上に、１対のパターニングされた第１の反強磁性層４４ａ、４４ｂが形成されている。第１電極４３、絶縁層４２および第１の反強磁性層４４ａ、４４ｂ上に、下地層５５が形成されている。下地層５５上に、第１フリー層４５、スペーサ層４６および第２フリー層４７を含むＣＰＰ－ＭＲ膜が形成されている。第２フリー層４７の一部上に保護層５７が形成されている。トラック幅方向（ｙ方向）に沿って第２フリー層４７の両側部に接して、１対のパターニングされた第２の反強磁性層４８ａ、４８ｂが形成されている。保護層５７および第２の反強磁性層４８ａ、４８ｂ上に絶縁層４９が形成され、その一部がエッチングされ、そこに第２フリー層４７に接するピラー形状の第２電極５０が埋め込まれている。絶縁層４９および第２電極５０上に、上部シールド５１が形成されている。

【００６４】フリー層およびスペーサ層には、第１の実施形態において説明したのと同様な材料を用いることができる。

【００６５】下地層および保護層の材料としては、非磁性金属たとえばＴａ、Ｔｉ、Ｃｕ、Ｒｕ、ＡｕおよびＣｒなど、ならびに軟磁性材料たとえばＮｉＦｅ（パーマロイ）および非晶質ＣｏＺｒＮｂなどが挙げられる。

【００６６】反強磁性層としては、ＰｔＭｎ合金、ＰｔＰｄＭｎ合金、ＣｒＭｎ合金、ＣｒＰｔＭｎ合金、ＩｒＭｎ合金、ＲｈＭｎ合金などが用いられる。反強磁性層のパターンは、以下のような方法によりを形成することができる。（ｉ）反強磁性体を成膜し、フォトリソグラフィープロセスによりレジストをパターニングし、レジストをマスクとしてイオンミリングにより反強磁性層のパターンを形成した後、レジストを除去する。（ｉｉ）フォトリソグラフィーによりレジストをパターニングし、フリー層上の保護層を除去し、反強磁性体を成膜した後、リフトオフによってレジストおよびその上の反強磁性体を除去することにより、反強磁性層のパターンを形成してもよい。

【００６７】反強磁性体層と電極との間に形成される絶縁層には、$SiO_2$や$Al_2O_3$などが用いられる。なお、反強磁性層がフリー層に対して十分比抵抗が大きい場合には、必ずしも絶縁層を形成しなくてもよい。絶縁層を形成する場合には、少なくともどちらか一方の電極に対して形成すればよいが、両方の電極に対して形成することがさらに好ましい。フリー層と電極との接触部のサイズは、絶縁層の開口部により規定される。

【００６８】このＣＰＰ－ＭＲヘッドにおいても、センシング部は第１電極４３および第２電極５０に挟まれたＣＰＰ－ＭＲ膜の部分である。このセンシング部は、第１フリー層４５、スペーサ層４６および第２フリー層４７を含む。一方、パターニングされた反強磁性層４４ａ、４４ｂ、４８ａ、４８ｂはセンシング部からはずして形成されている。したがって、このＣＰＰ－ＭＲヘッドでも、第１の実施形態と同様に、狭ギャップを実現できる。

で、互いに反平行になるため、出力電圧は$+V_{pp}$という最高値を示す。

【0086】以上のように信号磁束を検出することにより、記録ビットの遷移領域を検出できる。この動作原理を用いる場合、磁束は第1フリー層45から第2フリー層47へ、または第2フリー層47から第1フリー層45へと流れるので、1対の磁気シールドは必ずしも設ける必要はない。

【0087】（他の実施形態）図12は、他の実施形態のCPP－MRヘッドに用いられるCPP－MR膜を媒体対向面に垂直な面で切断した断面図である。図12のCPP－MR膜は、図1（a）と同様に、下地層31、第1フリー層23、スペーサ層24、第2フリー層25、保護層32が積層されている。しかし、図12のCPP－MR膜では、スペーサ層24がそれぞれ第1フリー層23または第2フリー層と接する1対の第1スペーサ層24aと、1対の第1スペーサ層24aに挟まれるように形成された第2スペーサ層24bとを含む3層構造になっている。

【0088】上述したようにスペーサ層の膜厚は本発明の実施形態に係るCPP－MRヘッドを設計する上で非常に重要である。従って、設計の自由度を増すためにも、スペーサ層にはスピン拡散長を十分に長く設定できるような材料を選ぶことが好ましい。

【0089】スピン拡散長が長い材料としてはAl、Mg、Be、Caのような原子量の小さい元素からなる金属またはそれらを含むような合金が挙げられる。Al、Mg、Be、Caのスピン拡散長は、室温で約200nm程度である。従って、スペーサ層の一部にAlまたはMg層を用いることが適当である。また、電気伝導率の低いCu、Au、Ag、Rh、Ru、Irなどの材料もスピン拡散長が長く、スペーサ層の材料として好ましい。我々の研究の結果、これらの材料ではスピン拡散長が50nm以上あると考えられる。

【0090】特に好ましい積層構造として、［第1スペーサ層／第2スペーサ層／第1スペーサ層］の3層構造が挙げられる。第1スペーサ層には、Au、Cu、Ag、Rh、Ir、Ruから選択される金属が用いられる。第2スペーサ層には、Al、Mg、Be、Caから選択される金属が用いられる。この積層構造では、第2スペーサ層によりスピン拡散長を調整し、第1スペーサ層と第1フリー層または第2フリー層との界面においてスピン依存散乱の効果を与える。

【0091】第1スペーサ層の膜厚はスピン拡散長をできるだけ伸ばすために10nm以下であることが好ましい。第2スペーサ層の膜厚は、スピン拡散長よりも短くなるように、200nm以下であることが好ましい。

【0092】また、フリー層中のスピン拡散長も考慮すると、CPP－MR膜のフリー層とスペーサ層の膜厚の合計は、第2スペーサ層のスピン拡散長の50％以下であることが好ましい。ここで、フリー層の膜厚とはスピン依存散乱に寄与する部分の膜厚を意味する。すなわち、単純フリー層の場合には全膜厚、シンセティック・フリー層の場合にはRu層の膜厚とスペーサ層側の磁性層の膜厚とを合計した膜厚のことを指す。

【0093】本発明の他の実施形態に係る磁気抵抗効果ヘッドには、図13または図14に示した磁気抵抗効果膜を用いることもできる。

【0094】図13は、第1フリー層61、$Al_2O_3$などの酸化物で形成されたスペーサ層62および第2フリー層63を積層したトンネル型磁気抵抗効果膜（TMR）の断面図である。TMR膜では、素子抵抗を考慮するとスペーサ層62の厚さは5nm以下であることが好ましい。スペーサ層62には、たとえば$Al_2O_3$などのAl酸化物、$Fe_3O_4$などのFe酸化物、LSMOなどのペロブスカイト型酸化物から選択される少なくとも1層を用いることができる。

【0095】図14は、図13と同様な構造を有するTMR膜であるが、スペーサ層62として［金属層62a／酸化物層またはチッ化物層62b／金属層62a］の積層体を用いている。中間の酸化物層またはチッ化物層62bは必ずしも連続膜である必要はなく、非連続であってもよい。酸化物層またはチッ化物層62bが連続膜になっているか否かは、電子顕微鏡観察によって確認することができる。

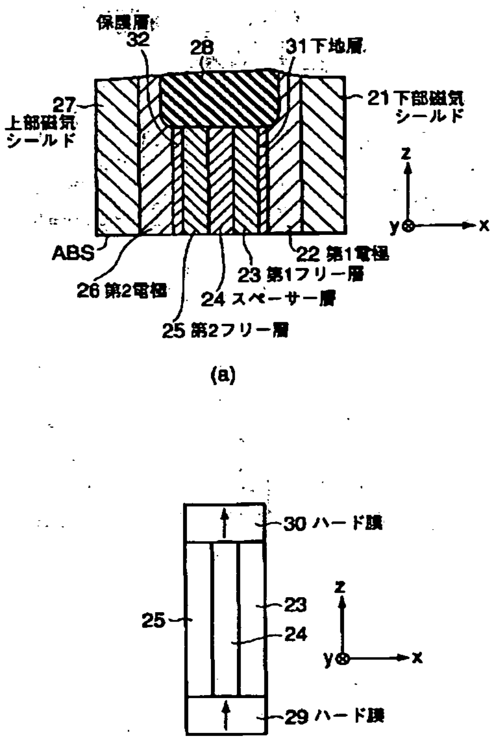
【0096】次に、本発明に係るCPP－MRヘッドを搭載した磁気ヘッドアセンブリ、およびこの磁気ヘッドアセンブリを搭載した磁気ディスク装置について説明する。

【0097】図15（a）はCPP－MRヘッドを搭載した磁気ヘッドアセンブリの斜視図である。アクチュエータアーム201は、磁気ディスク装置内の固定軸に固定されるための穴が設けられ、図示しない駆動コイルを保持するボビン部等を有する。アクチュエータアーム201の一端にはサスペンション202が固定されている。サスペンション202の先端にはCPP－MRヘッドを搭載したヘッドスライダ203が取り付けられている。また、サスペンション202には信号の書き込みおよび読み取り用のリード線204が配線され、このリード線204の一端はヘッドスライダ203に組み込まれたCPP－MRヘッドの各電極に接続され、リード線204の他端は電極パッド205に接続されている。

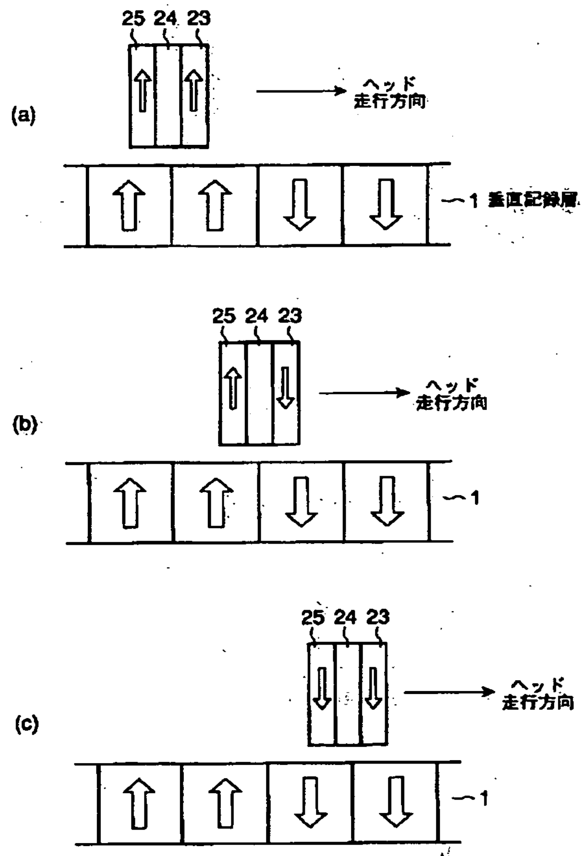
【0098】図15（b）は図15（a）に示す磁気ヘッドアセンブリを搭載した磁気ディスク装置の内部構造を示す斜視図である。磁気ディスク211はスピンドル212に装着され、図示しない駆動装置制御部からの制御信号に応答する図示しないモータにより回転する。アクチュエータアーム201は固定軸213に固定され、サスペンション202およびその先端のヘッドスライダ203を支持している。磁気ディスク211が回転する

２０３…ヘッドスライダ
２０４…リード線
２０５…電極パッド
２１１…磁気ディスク
２１２…スピンドル
２１３…固定軸
２１４…ボイスコイルモータ

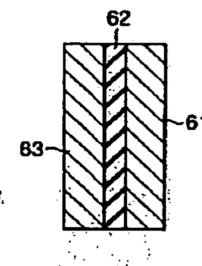
【図１】



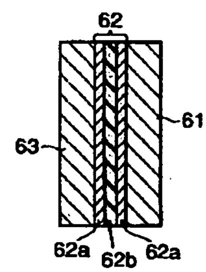

【図２】



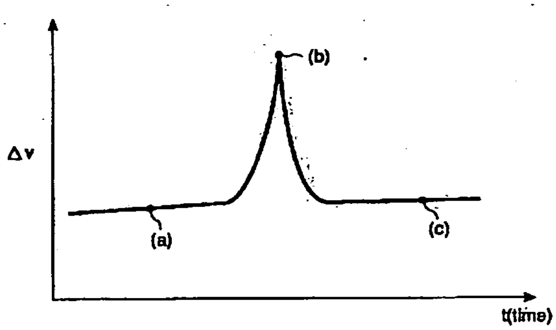

【図１３】



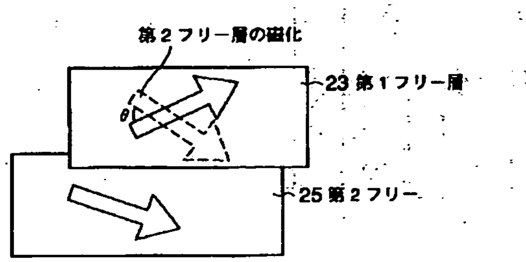

【図１４】



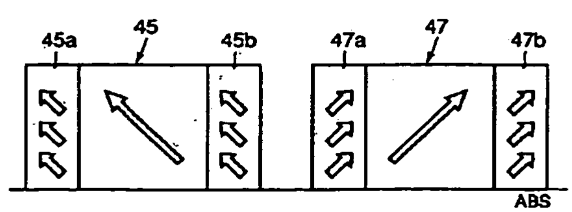

【図３】



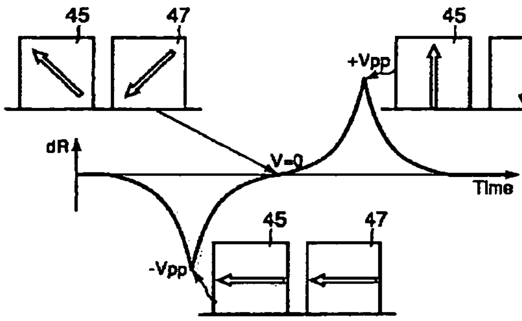

【図４】



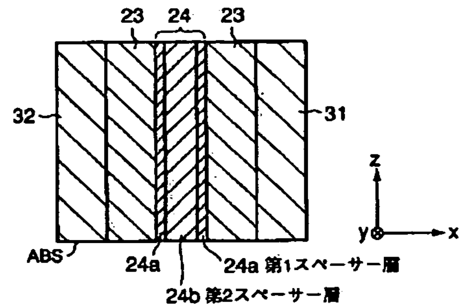

【図８】



【図１１】

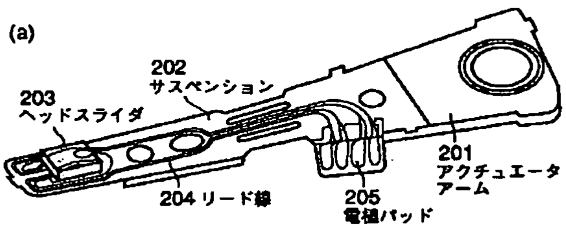



【図１２】

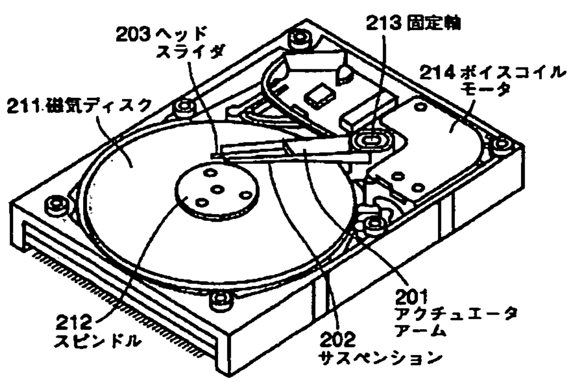



【図１５】

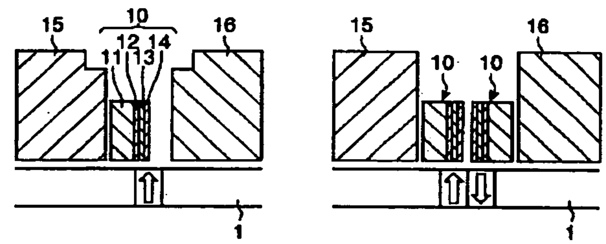
(a)




(b)




【図１６】




(a)　　(b)

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(72) 発明者　高岸　雅幸
神奈川県川崎市幸区小向東芝町１番地　株式会社東芝研究開発センター内

(72) 発明者　湯浅　裕美
神奈川県川崎市幸区小向東芝町１番地　株式会社東芝研究開発センター内

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